AFRL-SR-AR-TR-09-0118

REPORT DOCUMENTATION PAGE

1. REPORT DATE *(DD-MM-YYYY)* 20-02-2009	**2. REPORT TYPE** Final	**3. DATES COVERED** *(From - To)* 01-02-08 to 30-11-08

4. TITLE AND SUBTITLE

(HBCU/MI) Radiometric Measurements on Ag/n-Si Composite Films for Detecting Radiation in the Earth's Atmospheric Windows

5a. CONTRACT NUMBER

5b. GRANT NUMBER FA9550-08-1-0008

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

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5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

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8. PERFORMING ORGANIZATION REPORT NUMBER

0005581

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11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT

Distribution A - Approved for public release

20090429202

13. SUPPLEMENTARY NOTES

14. ABSTRACT

The objectives of the research proposed in this ten month effort were to assemble optical absorption and radiometric facilities for measuring the properties of Ag/n-Si composite films that are to be used as infrared detectors in the earth's atmospheric windows (1-2, 3-5 and 8-12 microns) from room down to liquid nitrogen temperatures and to begin making these measurements on films with specific microstructures. All of the equipment requested in the original proposal is now in place and measurements of the optical properties using the FTIR equipment have replicated data taken at the Johns Hopkins University Applied Physics Laboratories. Measurements of the radiometric properties have not yet begun. The delay in getting this equipment was a combination of manufacturers delivery times after receipt of order and university delays in processing purchase orders. In addition to the above described work, we have developed a theory for the internal quantum efficiency of these films that use only experimentally determined quantities. This theory indicated that for applied electric fields on the order of 10+e6 volts/cm this efficiency at room temperature can be as high as 35% depending on the incident wavelength, providing a strong justification for pursuing the research being undertaken.

15. SUBJECT TERMS

Optical absorption, Responsivity, signal-to-noise ratio

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON / 19b. TELEPHONE NUMBER *(Include area code)*
U	U	U	SAR	2	Clayton W. Bates, Ph.D. / 202-806-6147

Final Report covering the period 01-02-008 to 30-11-008
AFOSR
Grant # FA9550-08-1-0008
Program Manager – Dr. Donald Silversmith

Radiometric Measurements on Ag/n-Si Composite Films for Detecting Radiation in the Earth's Atmospheric Windows

I. Background

Ag/n-Si composite films are being investigated for detecting radiation in the earth's atmospheric windows (1-2, 3-5 and 8-14µms). Detection occurs by tunneling of photoexcited electrons in the Ag nanoparticles through the Ag-Si Schottky barrier into the n-type silicon conduction band. To evaluate the efficiency of this process the optical and radiometric properties of these films as a function of Ag particle size distribution and volume fraction must be made. To date these measurements have been performed at separate collaborating facilities resulting in large time delays associated with preparing samples at one site and then sending them out for measurement and evaluation at another or other sites. These delays were found to be excessively long, due in no small measure to the fact that there are few setups nationwide for making these measurements and they are in constant use for other applications. Due to this situation few radiometric measurements have been made on these films and none on well characterized ones. This proposal was in the nature of an equipment grant, consisting in acquiring and setting up facilities for making optical absorption, responsivity, detectivity and signal-to-noise measurements on Ag/n-Si composite films as a function of microstructure from room down to liquid nitrogen temperatures. All of the equipment specified in the original proposal has been acquired and measurements are presently underway to characterize the Ag/n-Si composite films. The delay in getting and setting up this equipment was a combination of manufacturers' delays in shipping (up to four months for some parts), institutional delays in processing purchase orders (three months after the grant was received), the repair of a faulty, as delivered, blackbody source (2 months) and the training and certification of the postdoctoral research associate for using the FTIR (one month), such that it has only been this month (February) that measurements of any kind have been possible.

II. Technical Discussion

Optical measurements using FTIR have been made on Ag/n-Si composite films 3µm thick consisting of 20 at.% Ag prepared at 550 C. They are in good agreement with those made at Johns Hopkins University Applied Physics Laboratory on films similarly prepared. With no antireflection coatings these films have absorptions of 60 to 70% in the 1-2µm range, 50 to 45% in the 3-5µm range and 37 to 32% in the 8-14µm range. No radiometric measurements have been taken at this time, but the experimental setup has been tested using a standard diode and found to be in working order. Composite films for these measurements are presently being prepared.
In parallel with setting up the facilities for making optical and radiometric measurements we have developed a theory giving an expression for determining the internal quantum

efficiency that depends only on experimentally determined quantities. This theory indicates that for electric fields on the order of 10^6 volts/cm, room temperature quantum efficiencies of between 10 to 35% are possible depending on the particular incident wavelength and that electric fields smaller than this amount should give little to no signal current. It is an important result because it provides a justification for pursuing this research effort. This is the first time that such an expression has been derived for metal-semiconductor composite systems. The work was recently published in the Journal of Applied Physics **104**, 076101 (2008). This theory was recently applied to radiometric measurements made on a composite film at the Johns Hopkins University Applied Physics Laboratory that produced a signal current at liquid nitrogen temperature with incident radiation in the 8-14μm wavelength range and indicated that the electric field was $3.3\text{x}10^6$ volts/cm in complete agreement with the theory. It further suggests that a major effort in these investigations should be in the improvement of the transport properties of the silicon matrix so that after the photoexcited electrons tunnel through the Schottky barrier into the n-type silicon conduction band they do not recombine or are trapped before getting to a contact.